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# Metals and Alloys on Boats and How to Reduce Their Risks

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## (Explanation of the Galvanic Series)

# Corrosion of Metals on Your Vessel and How to Reduce its Risk

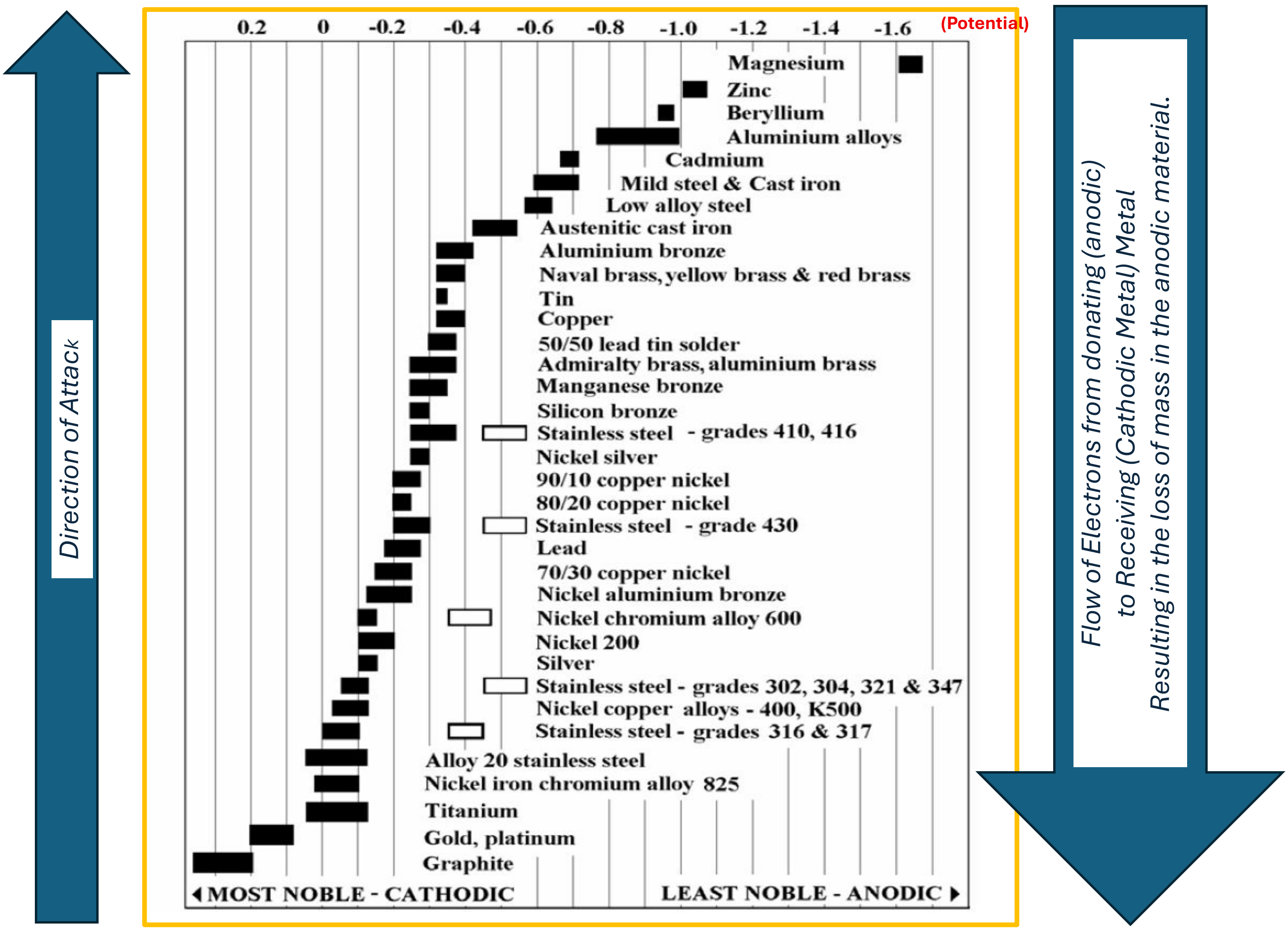
**(Explanation of the Galvanic Series)**

In this short essay I want to explain how dissimilar metals (alloys) interact with each other electrochemically and give some insights into how you can plan and implement a strategy to reduce the impact of galvanic corrosion.

When it comes to building or maintaining a vessel, most owners and builders are alert to corrosion. Yet one of the most common – and costly – mistakes is mixing metals without considering the galvanic series. This oversight can eat through fittings, weaken hull structures, and undermine safety.

## What is the Galvanic Series?

The galvanic series is a ranking of metals and alloys by their electrochemical potential in a specific environment or electrolyte, such as seawater. - Metals at the top of the series (anodic, active) are more likely to corrode. - Metals at the bottom (cathodic, noble) are more resistant. - When two different metals are joined in a conductive environment (like seawater), the more active one corrodes (anode), while the more noble one is protected (cathode). In short: the anodic metal sacrifices itself to save the noble metal.




**Test conditions used for determining values shown in the series above.**

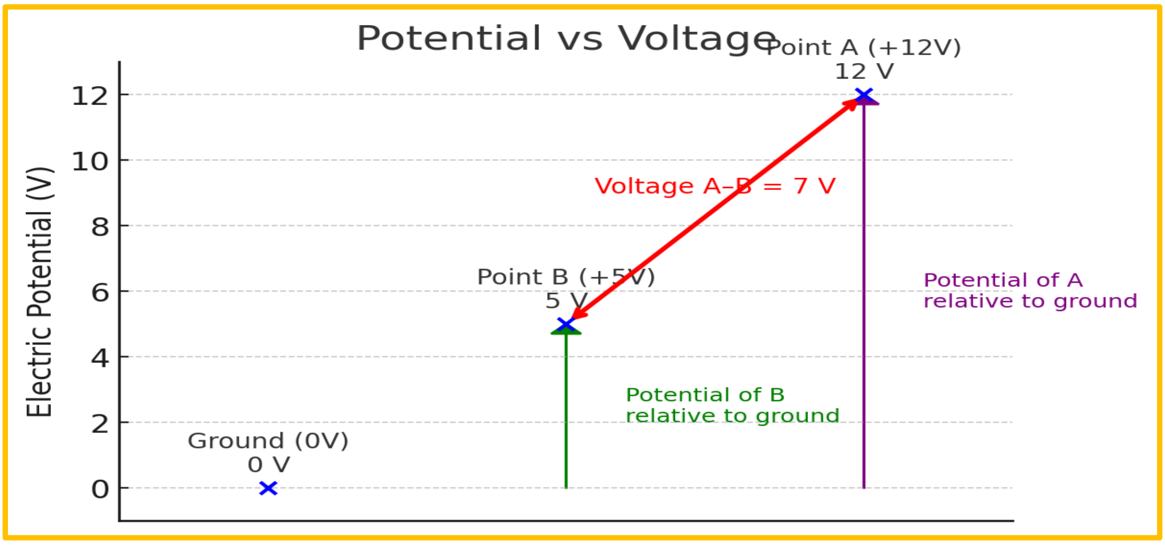
- The electrolyte for the purpose of determining the readings above was sea water.
- The test electrode used to determine the table values was silver/silver chloride (Ag/AgCl)
- Temperature affects electrical activity. The temperature at which these values were determined was 25$^{o}$C.

A key point in understanding the Galvanic Series is that it measures the 'relative' potential of one material to another, rather than an absolute value. Each metal has been tested against a specific electrode to determine how it behaves compared to others. In this context, 'potential' refers to the tendency of a metal to lose electrons compared to another, while 'voltage' typically describes the measurable electrical difference between two points. If you want to compare two metals (or alloys), the series provides a way to see how the two materials performed in the test relative to each other.

For example, if zinc and copper are compared using the Galvanic Series, zinc has a lower potential than copper, meaning it is more likely to corrode when both are in contact within an electrolyte such as seawater. So, values represent potential rather than voltage, helping you predict which metal is more susceptible to corrosion.

Put another way:

***Voltage & Potential – What is the difference?***




In the diagram above each point has its own **potential** relative to ground (0 V). The **voltage** is the **difference** in potential between two points (A – B = 7 V in this case).

So:

- **Potential** = The value at one point. The greater the value on the table the greater potential for flow of electrons
- **Voltage** = The difference between two potentials.

# Interpretation

Metals that are less than **200mV** apart on the scale will corrode with each other slowly.

Readings which are **200mV to 400mV more negative** indicate that the material is more anodic and that it is protected.

Readings at or **near those shown** in the table and up to **200mV above** that value are indicative of a material that is unprotected and corroding freely. You must take steps to protect them by insulating or isolating them from each other or using anodes.

Readings over **400mV more negative** than the table value is an indication of **overprotection.**

**Overprotection** in the galvanic series means the potential is made too negative, so instead of reducing corrosion, it causes side effects such as:

- **Hydrogen damage -** causes hydrogen gas to form on the surface of the metal. On steels, this can lead to hydrogen embrittlement or cracking.
- **Stress on welds/joints**: Localized hydrogen effects can weaken welded structures.
- **Coating failure** - Disbonding or blistering of protective coatings (the paint or epoxy lifts off).
- **Excess anode consumption**: Sacrificial anodes or impressed current anodes are consumed much faster, increasing cost and maintenance.

**Stray Current -** If a metals reading is more cathodic i.e. more positive, it can mean that the metal surface is being supplied with external electrons. This is a diagnostic sign of stray current problems.

**Examples:**

Mild steel will hold onto its electrons more strongly than aluminium. When both are together in seawater aluminium as the more anodic will corrode faster than the mild steel.

Silicon Bronze retains its electrons more than mild steel. Mild steel is anodic to the silicon bronzes cathodic.

# The Galvanic Series in Seawater vs Freshwater

Below is a simplified dual-column chart showing how common marine metals rank in seawater (left) and freshwater (right).

**Galvanic Series in Seawater vs Freshwater Simplified**

| SEA WATER | FRESH WATER |
|---|---|
| | **Magnesium – Corrodes Very Easily** |
| **Magnesium – Corrodes Very Easily** | |
| | Zinc (Galvanising) – Sacrificial Anode |
| Zinc (Galvanising) – Sacrificial Anode | |
| | **Aluminium Alloys – Active. Corrode if unprotected** |
| **Aluminium Alloys – Active. Corrode if unprotected** | Mild Steel / Cast Iron – Corrodes Readily |
| Mild Steel / Cast Iron – Corrodes Readily | **Lead / Tin – More Stable** |
| **Lead / Tin – More Stable** | |
| | **Copper, Brass, Bronze – Quite Noble** |
| **Copper, Brass, Bronze – Quite Noble** | |
| | **Nickel / Monel - Noble** |
| **Nickel / Monel - Noble** | |
| | Stainless Steel (Passive) – Very Noble |
| **Stainless Steel (Passive) – Noble if film intact; may pit** | |
| | **Titanium, Platinum and Gold – Almost immune** |
| **Titanium, Platinum and Gold – Almost immune** | |

# Why Boats are Especially Vulnerable

A vessel provides nearly perfect conditions for galvanic corrosion:

1. **Different metals in contact** – Aluminium hulls with stainless fasteners, bronze props on steel shafts, zinc anodes bolted to everything.

2. **A conductive electrolyte** – Saltwater is one of the best natural electrolytes. Even freshwater is conductive enough to cause problems.

3. **Electrical continuity –** Bonding systems, through-hull fittings, and even water films create pathways for electron flow. All it takes is the right metal combination and moisture to set up a miniature battery on your hull.

# Common Problem Scenarios

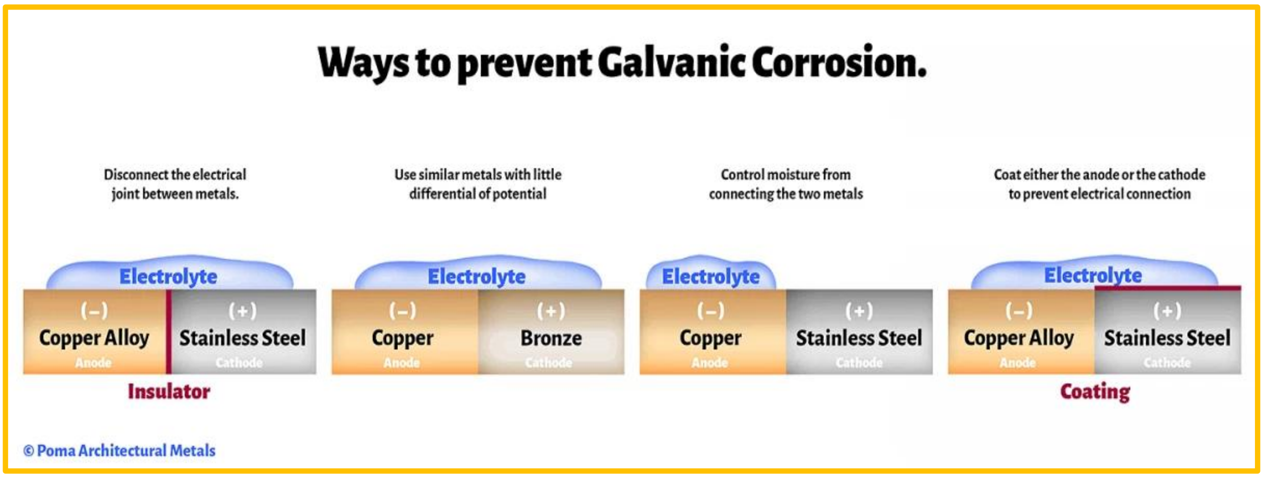
Stainless fasteners in aluminium hulls: The stainless is noble, the aluminium is active. Result: powdery white corrosion pits in the aluminium around the screw heads. –

Bronze propellers on steel shafts: Bronze is noble, so the steel corrodes faster at the shaft–propeller junction.

Unprotected aluminium outdrives: Without sacrificial zinc or aluminium anodes, the outdrive itself becomes the anode and corrodes rapidly.

# Practical Guidelines to Avoid Trouble

The following are some guidelines to mitigate galvanic corrosion. These cover most, but not all, possible measures.




**In the image above different strategies are visualized to mitigate the onset of galvanic corrosion between two dissimilar metals(alloys).** These include:

- Remove the electrical connection between the materials using an insulator.
- Use dissimilar metals with slight difference in potential.
- Control the presence of electrolyte e.g. moisture.
- Coat the anode or cathode with barrier material to prevent an electrical connection.

Other measures include:

1. Consult the galvanic series for your environment. -

2. **Seawater-** The spread in potential is large and corrosion is fast.

3. **Freshwater -** The spread is smaller, but corrosion still occurs.

4. In metal hulls avoid having dissimilar metals touching anywhere on the hull.

5. Avoid wide separations in the series.

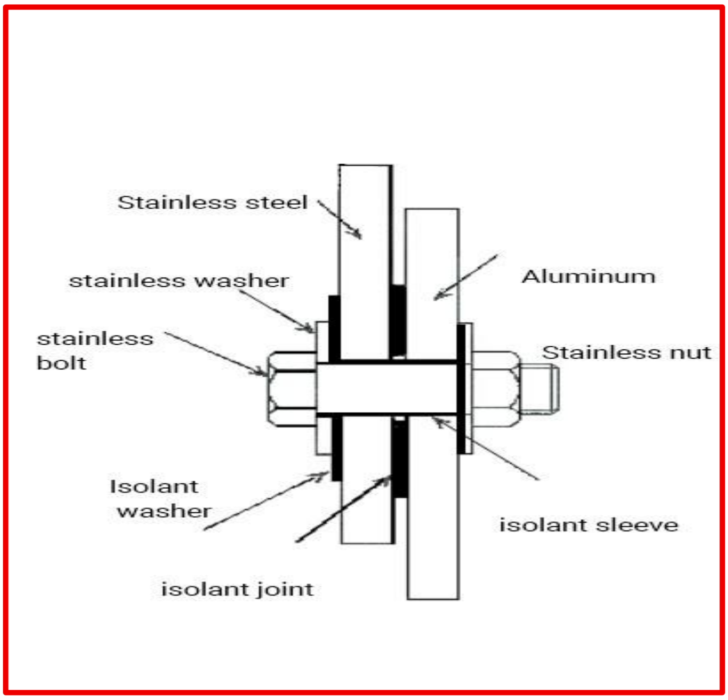
6. Do not pair metals that are far apart unless protection is in place.

7. Use sacrificial anodes wisely. Zinc, aluminium, or magnesium anodes corrode instead of your hull, shaft, or fittings.

8. Control the area ratio. A small anodic area attached to a large cathodic area will corrode very quickly e.g., an undersized anode for a given area.

   Isolate metals where possible. Use non-conductive washers, gaskets, or coatings to break the circuit.

9. Maintain electrical systems. Stray currents can accelerate galvanic action, so regularly check bonding and shore power. Install a galvanic isolator on the shore power circuit.




10. On metal hulled vessels Bronze Seacocks and fittings should be isolated from metal hulls. The ABS, Lloyds and the US Coast Guard have approved GRP reinforced with nylon seacocks (Forespar make). Note though that these will melt. Check your applicable commercial regulations as they may require metal seacocks.

**In the image on the left is presented a plate of stainless steel being bolted to a plate of aluminium. If no protection is implemented between the two plates the aluminium will corrode due to galvanic corrosion in the presence of an electrolyte such as sea water and the cathode of stainless steel. An isolation joint, washer and sleeve are used to prevent direct contact between the plates.**


Problems can occur with traditional mechanical means such as used above or when the fusion welding of two metals is not possible.

A more modern method to that shown above such as TriClad® maybe used, TriClad® is a structural transition joint patented by Merrem & la Porte which is mainly used in luxury yacht building and navy.

DMC NobelClad is the largest explosion welding organization in the world and supplies the board material for the Triclad® strip.

TriClad® are Lloyds 3.2 approved. They use a patented bonding process that is certified according to the Military Specification MIL-J-24445A.

# Key Takeaways

On a vessel, you cannot avoid mixing metals completely — props, shafts, fasteners, and fittings all have different requirements. But you can avoid uncontrolled galvanic corrosion by:

Understanding where metals sit in the galvanic series,

Choosing compatible combinations,

Installing sacrificial anodes

Using isolation and coatings where necessary.

If ignored, galvanic corrosion can turn your vessels carefully engineered systems into a slow-motion self-destruct mechanism. With proper attention, you can ensure that only the cheap, replaceable anode corrodes — and not your hull or fittings.

# References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